ISIS - A SOFTWARE ARCHITECTURE FOR PROCESSING PLANETARY IMAGES. J.M. Torson and K.J. Becker, *U.S. Geological Survey, 2255 N. Gemini Drive, Flagstaff, AZ 86001, jtorson@flagmail.wr.usgs.gov*

INTRODUCTION: ISIS (Integrated Software for Imaging Spectrometers) is a generalized software system that has been designed to optimize cartographic and scientific processing of mulitspectral and hyperspectral images in planetary datasets. ISIS is capable of processing both single-band and multiband images of the Viking, Voyager, Clementine (11-band), Galileo SSI (7-band), and Galileo NIMS (408-band) missions [1, 2].

OPERATING ENVIRONMENT: ISIS runs on a variety of UNIX platforms, including Sun (SOLARIS), DEC Alpha (DEC UNIX), and Silicon Graphics. In addition, support for PCs running LINUX is under development. ISIS includes portable interactive display programs that use the standard X Window System environment on 8-bit and 24-bit workstation displays as well as X terminals. ISIS was originally developed in the VAX/VMS operating system, and a VAX/VMS version of ISIS is available that uses the older DEC workstation environment and the IVAS image display device.

USER INTERFACE: Most of ISIS is implemented as a collection of separate application programs that operate within the Transportable Applications Environment (TAE), which was developed by the NASA Goddard Space Flight Center. The "Classic" version of TAE that is used provides a text terminal interface that allows the user to specify a set of parameter values that are to be used on a given run of an application program. TAE includes a "tutor" mode that provides on-line help information for each application program. Hard-copy program documentation can also be produced. In addition, TAE provides a programming language that allows creation of procedures that execute a sequence of application programs. These procedures can be run interactively or as batch jobs.

SESSION LOG FILE: ISIS automatically maintains a session log file that contains a record of each program that a user runs. This includes a record of the parameter values used and any additional information generated by the individual application programs.

CUBE FILES: The primary disk file format used by application programs is the ISIS cube file, which contains a label area and a data area. The label describes the data and uses a "keyword=value" text format. This is a version of the NASA Planetary Data System (PDS) label format that is adapted for allowing on-line processing in addition to archival (read-only) storage. The label is normally imbedded in the data file, but ISIS also supports "detached" labels stored in files that are separate from the associated data.

The data area of a cube file contains at least two data objects. The first is the History data object, which contains an automatically maintained record of the processing history of the file. The Cube data object contains the three-dimensional spatial-spatial-spectral (sample, line, band) array of image data. (Single-band images are stored as cubes in which the band dimension has a length of one.) Three different physical storage orders are supported to allow optimizing spatial or spectral processing operations. Pixels can be stored in 8-bit, 16-bit, or 32-bit format, which allows trade-offs between disk storage usage and precision of stored values. From the user's point of view, pixels are always floating point (real) values. For 8-bit and 16-bit formats, label keywords provide additive and multiplicative values that convert the "raw" 8-bit or 16-bit integer values into the floating point values being represented. This allows direct representation of derived non-integer values or values less than one (e.g., ratios) in all three pixel formats. In addition to valid numerical pixel values, five types of "special" pixel values are supported: null, high/low instrument saturation, and high/low representation saturation. (Most applications use 32-bit floating point arithmetic for internal computations. Representation saturation values are used for output to 8-bit or 16-bit files when valid computed values lie outside the range that can be represented with the current additive and multiplicative conversion values.)

In addition to the "core" image data, a Cube data object can optionally contain "suffix" data, which consists of an arbitrary number of planes of data that extend any of the three axes. The most common suffix planes extend the band dimension and are called "backplanes." These are used for storing auxillary data that are spatially registered with the image, e.g., latitude, longitude, phase angle, region-of-interest bit masks, etc.

INSTRUMENT SPECTRAL LIBRARY FILES: The second major type of ISIS disk file is the Instrument Spectral Library (ISL) file, which is used for storing collections of spectra and the associated header information that identifies each spectrum. All the spectra in a given ISL file have the same set of wavelengths, which corresponds to one of the observing modes of a given instrument. Different ISL files can contain different sets of wavelengths. ISL files can be used for storing data obtained from laboratory spectral measurements. ISL files can also be used for storing spectra (or average spectra) that are extracted from cubes of data produced by flight instruments.

TABLE FILES: The third major type of ISIS disk file is the table file. A typical example of a table file is an average spectrum file containing data for a given spatial area. Each row of the table corresponds to one wavelength band of the spectrum and contains several different data values, e.g., band number, wavelength, average spectrum value, standard deviation, etc. Different table files can have different numbers of rows or columns in order to serve various instrumental and analysis objectives. An ISIS table file contains a label area and history object (which are similar to a cube file label and history) and a data object that contains the table data stored in a binary format. This format has a number of advantages over an ASCII table format, e.g., automatic maintenance of history information, access to data columns by name, avoidance of ASCII formatting problems, and preser-

vation of ISIS special pixel values. Utility programs are provided for converting between binary and ASCII formats when needed for listing data values or exchanging data with other software packages.

APPLICATION PROGRAMS: The UNIX version of ISIS currently contains more than 130 application programs. Some of these implement functions derived from the older VAX/VMS version of ISIS and the older VAX/VMS Planetary Image Cartography System (PICS). Categories of functionality include data ingestion, cosmetic processing, radiometric correction, geometric rectification, photometric correction, image mosaicking, and various analysis functions. Mission-specific processing software is provided for Clementine, Galileo NIMS, Galileo SSI, Mariner, Viking and Voyager.

INTERACTIVE DISPLAY PROGRAMS: ISIS includes several portable interactive display programs that operate on standard X Window System display devices and provide a graphical user interface for controlling display operations. Most of these programs are implemented using the Interactive Data Language (IDL) from Research Systems, Inc. One of these programs ("tvtie") allows interactive definition of control points and match points for updating instrument camera angles and producing mosaics of multiple images. Another ("cv") provides a variety of functions for visualizing cube files, e.g., displaying selected spatial-spatial or spatial-spectral slices through the cube; "movie" display of different slices; displaying backplanes; reporting coordinates, wavelengths, and pixel values; zoom/roam; plotting spatial profiles, single spectra, and average spectra for arbitrary spatial regions; and hard-copy (PostScript) output. This program can also plot Instrument Spectral Library data for comparison with spectra in observation cubes. Finally, ISIS includes a display program ("qview") that does not require the IDL language and that provides additional functions such as 3-band RGB color composite display.

ADDITIONAL INFORMATION: Additional information about ISIS is available on the World Wide Web at http://wwwflag.wr.ugsg.gov/ISIS. This includes extensive documentation on the overall ISIS architecture, detailed descriptions of the available application programs, and information on obtaining a copy of the ISIS software.

REFERENCES: [1] Gaddis, L., An Overview of the Integrated Software for Imaging Spectrometers (ISIS), this volume; [2] Eliason, E., Production of Digital Image Maps with ISIS, this volume.